Code: AE61 **Subject: CONTROL ENGINEERING**

AMIETE – ET (NEW SCHEME)

JUNE 2012

Time: 3 Hours **Max. Marks: 100**

PLEASE WRITE YOUR ROLL NO. AT THE SPACE PROVIDED ON EACH PAGE IMMEDIATELY AFTER RECEIVING THE QUESTION PAPER.

NOTE: There are 9 Questions in all.

- **Question 1 is compulsory and carries 20 marks. Answer to Q.1 must be written in the space provided for it in the answer book supplied and nowhere else.**
- **The answer sheet for the Q.1 will be collected by the invigilator after 45 minutes of the commencement of the examination.**
- **Out of the remaining EIGHT Questions answer any FIVE Questions. Each question carries 16 marks.**
- **Any required data not explicitly given, may be suitably assumed and stated.**

Q.1 Choose the correct or the best alternative in the following: **(2×10)**

a. For an ideal lever shown in Fig.1, the displacement ratio $\left(\frac{x}{y}\right)$ and the force advantage $\left(\frac{F_1}{F_2}\right)$ are given by:

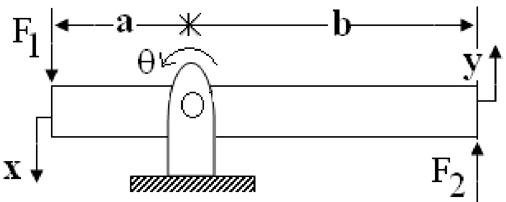

Fig.1

(A) $\frac{a}{b};\frac{b}{a}$ **(B)** $\frac{b}{a};\frac{a}{b}$

(C) $ab,\frac{a}{b}$ **(D)** $\frac{a}{b},ab$

b. For repetitive and/or hazardous tasks to be carried out at great speed and high precision, we use:

(A) control systems **(B)** servomechanisms

(C) robotics **(D)** mechanical system

c. If charge in electrical system is analogous to heat flow in thermal system, then current and voltage represent respectively:

(A) temperature and heat flow rate

(B) heat flow rate and temperature

(C) thermal resistance and thermal capacitance

(D) thermal capacitance and thermal resistance

d. The system sensitivity S_K^T to feedback gain K in $T=\frac{A}{1+KA}, A=10^4, K=0.1,$ is given by:

(A) -0.01 **(B)** -0.1

(C) 1 **(D)** -1

e. In the signal-flow graph shown in Fig.2 with an input disturbance torque $T_D(s)$ and $|G_1(s)G_2(s)H(s)| >> 1$, the ratio $\left(\frac{C_D(s)}{T_D(s)}\right)$ is given by:

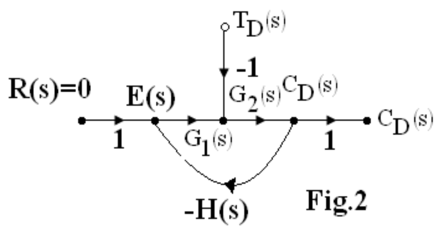

Fig.2

(A) $\frac{-G_2(s)}{G_1(s)H(s)}$ **(B)** $\frac{-1}{G_1(s)H(s)}$

(C) $\frac{G_1(s)+G_2(s)}{G_1(s)G_2(s)H(s)}$ **(D)** $\frac{-G_1(s)+G_2(s)}{G_1(s)G_2(s)H(s)}z$

f. With reference to Fig.3, where $\zeta=\cos\phi$ is the damping factor

$0 < \tan^{-1}\left(\frac{\sqrt{1-\zeta^2}}{\zeta}\right) < \frac{\pi}{2}$ is applicable for:

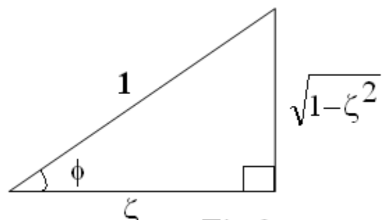

Fig.3

(A) $\zeta < 0$
(B) $\zeta \le 1$
(C) $0 < \zeta \le 1$
(D) $0 < \zeta < 1$

g. An incremental optical encoder used as a controller component having two channels and 30 sectors of disc (each sector being half transparent and half opaque) has improved basic resolution of:

(A) 3° **(B)** 30°

(C) 300° **(D)** 360°

h. If all the roots of the system $s^3 + 7s^2 + 25s + 39 = 0$ are to have real parts more negative than -1, then to check the relative stability, we should consider modified characteristic equation:

(A) $z^3 - 3z^2 - 14z + 39 = 0$ **(B)** $z^3 + 4z^2 + 14z + 20 = 0$

(C) $z^3 + 7z^2 + 28z + 14 = 0$ **(D)** $z^3 + 4z^2 + 11z + 13 = 0$

i. For the system $G(s) = \frac{9.7}{s(0.046s + 1)}$, at the corner frequency the value of $\angle G(j\omega)$ is :

(A) -135° **(B)** -90°

(C) -45° **(D)** 0°

j. If $r(t)$ is the input and $x_{1,2}$ are state-variables of the system $\begin{bmatrix}\dot{x}_1 \\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1 \\ -100 & -20\end{bmatrix}\begin{bmatrix}x_1 \\ x_2\end{bmatrix} + \begin{bmatrix}0 \\ 100\end{bmatrix} r$, then its characteristic equation is:

(A) $s^2 + s + 100 = 0$ **(B)** $s^2 + s + 20 = 0$

(C) $s^2 - 20s - 100 = 0$ **(D)** $s^2 + 20s + 100 = 0$

Answer any FIVE Questions out of EIGHT Questions.
Each question carries 16 marks.

Q.2 a. Define the terms:(i) Coulomb friction force (ii) Viscous friction force (iii) Stiction. Why is friction not always undesirable in physical systems? Explain the use of friction in the construction of the dashpot. **(3+2+3)**

b. The block-diagram of a speed control system is shown in Fig.4. Define the state variables and write the state and output equations of the system in vector-matrix form. **(8)**

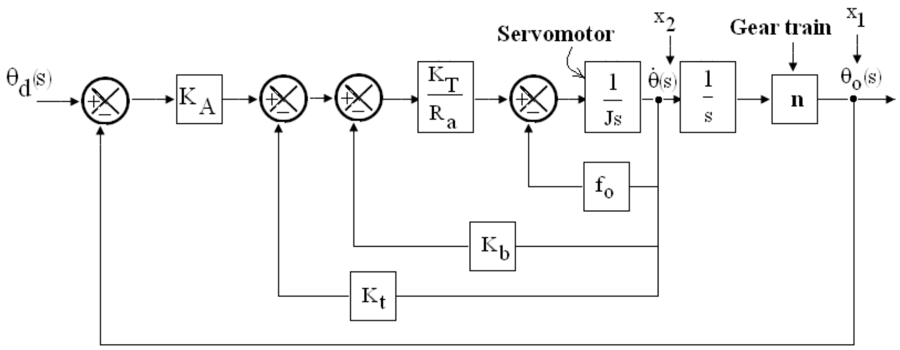

Fig.4

Q.3 a. Consider the block-diagram of a control system shown in Fig.5. Determine the condition the feed forward compensation $G_C(s)$ should satisfy to cancel out the effect of disturbance input $U(s)$ on the output $C(s)$.

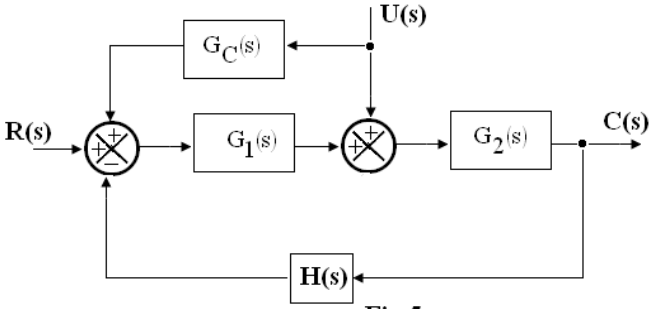

Fig.5

(8)

b. Draw s-domain signal-flow diagrams for the first-order systems:
(i) $\dot{x} = ax; x(t=0) = x(0)$ (ii) $\dot{x} = ax + bu; x(t=0) = x(0)$
(iii) $\dot{x} = ax + bu; x(t=0) = x(0) = 0; y = cx$
Where x is the state-variable, u is the input and y is the system output. Obtain the overall transfer function $T(s) = \frac{Y(s)}{U(s)}$ for case (iii) above. **(2× 4=8)**

Q.4 a. Determine the sensitivity S_α^T for the system shown in Fig.6. Evaluate S_α^T for $\omega = 0.1$ and 1 rad/s, with $\alpha = 2$ and $T(s) = \frac{C(s)}{R(s)}$. Does the sensitivity increase with frequency?

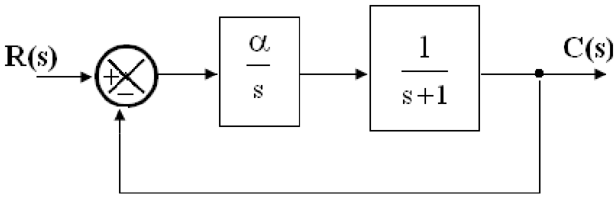

Fig.6

(3+4+1)

b. Draw the torque characteristics vs pulses/second for a stepper motor, indicating maximum torque, slew range, and pull-out torque. Explain with the help of a diagram, how a stepper motor can be used in closed-loop mode. **(4+4)**

Q.5 a. Show that the response c(t) of a second-order system $\frac{C(s)}{R(s)} = \frac{K}{Js^2 + Fs + K}$ to unit step input $r(t) = u(t)$ has a steady-state part and a transient part. Find the value of C_{SS} for $\zeta < 1$. **(8)**

b. A unity negative feedback control system has an open-loop transfer function consisting of two poles at -0.1 and 1, two zeros at -2 and -1, and a variable gain K. Using Routh-stability criterion, determine the range of values of K for which the closed-loop system has 0, 1 and 2 poles in the right-half s-plane. **(8)**

Q.6 a. Consider the feedback system $G(s) = K\frac{(s+b)}{s(s+a)}; H(s) = 1; s = \sigma + j\omega$. Using the angle criterion for the root-locus prove that $(\sigma + b)^2 + \omega^2 = (b^2 - ab)$. Hence, sketch the root-locus, taking a = 1, b = 2. **(5+3)**

b. Consider the open-loop transfer function $G(s)H(s) = \dfrac{K(s+z)}{s(s^2+2s+2)}$. After open-loop pole-zero cancellation, write the characteristic equation and sketch the root-locus. **(8)**

Q.7 a. At any point $G(j\omega) = x + jy$ on the polar plot of $G(j\omega)$, derive the equation of the constant-M circles, identifying the centre and radius. Draw typical family of M-circles with respect to $-1 + j0$ point on the x-axis. **(5+3)**

b. Obtain the sinusoidal transfer-function for the RC filter shown in Fig.7. Hence sketch the polar plot and the inverse polar plot for $0 \le \omega \le \infty$. **(2+3+3)**

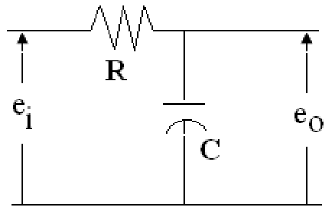

Fig.7

Q.8 a. Compare the advantages and applications of phase-lead and phase-lag compensators. **(8)**

b. A cascade compensator $G_C(s) = \dfrac{s+\alpha}{s}$ is used with a unity negative feedback system $G(s) = \dfrac{K}{s+4}$. Find the values of K and α to achieve 20% peak-overshoot and 1s settling time. Using these values of K and α, write the transfer function of the prefilter to cancel out the closed-loop zero. Calculate the steady-state error to unit ramp input. **(5+1+2)**

Q.9 a. An intelligent wheelchair is designed to move from place to place avoiding obstacles as shown in Fig.8. Write the canonical state-variable form of the complete system. Draw its block-diagram in state-variable form. **(5+3)**

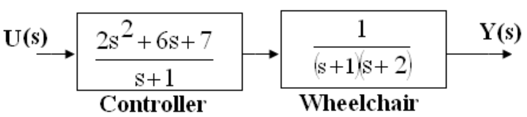

Fig.8

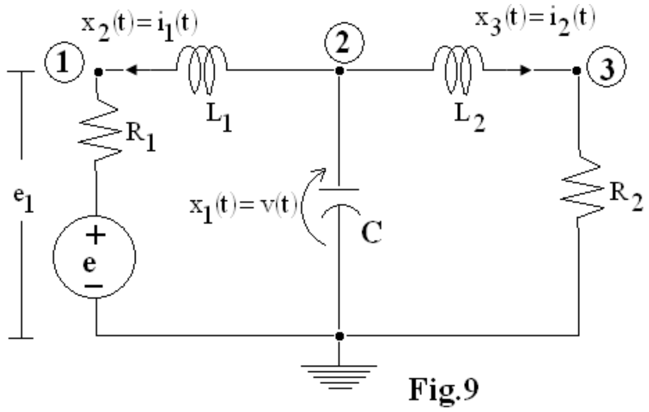

Fig.9

b. For the electrical system shown in Fig.9, $x_{1,2,3}$ are the state- variables and $y_{1,2}$ are output variables representing voltage across and current through R_2. Derive the state-model of the system. **(8)**